7.5　学位論文要旨（別紙様式博 5、例 1）

学位論文要旨

学位授与申請者

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題目：Biochar Induced Changes in Soil Microbial Communities and Activities in a Japanese Apricot Orchard (ウメ園におけるバイオ炭施用が土壌微生物群集および活性に及ぼす影響)

This study examines how biochar amendments and cover crops jointly affect soil microbes and disease suppression in Japanese apricot orchards and seedlings. Experiments tested rice husk and bamboo biochar, arbuscular mycorrhizal fungi, and cover crops (bahiagrass and white clover) for their roles in pathogen control, microbial diversity, and enzyme activities. Rice husk biochar notably reduced white root rot disease by enhancing plant biomass. Combined biochar and cover crop treatments fostered beneficial fungi and AMF, such as *Mortierellomycota* and *Acaulosporaceae*. Metagenomic and enzyme data linked AMF to specific enzyme activities under biochar amendment.

Chapter 1: General introduction. (序論)

Soil biological health provides the foundation for sustainable productivity and resilience in Japanese apricot (*Prunus mume*) orchards. Microorganisms, especially bacteria and fungi such as arbuscular mycorrhizal fungi (AMF), regulate decomposition, nutrient cycling, carbon sequestration, and plant health over time. However, modern management and soil degradation threaten these vital ecological functions. Integrative approaches, including biochar amendment and cover cropping, have emerged to restore microbial balance while sustaining yields. Biochar, produced by biomass pyrolysis, improves soil structure, fertility, and microhabitat conditions, providing recalcitrant carbon and facilitating nutrient retention, disease suppression, and enhanced microbial activity. Cover crops like bahiagrass and white clover enrich belowground biodiversity, support nitrogen fixation, and strengthen soil aggregation through continuous organic inputs and root exudation, also suppressing pathogens such as *Rosellinia necatrix.* This thesis is structured around three interlinked studies. The first investigates biochar's capacity to reduce soil-borne disease through plant status enhancement. The second uncovers how combining biochar and cover crops change bacterial communities. The third assesses if co-application also promotes beneficial fungal and AMF diversity. The work advances soil ecological engineering in perennial systems and offers practical strategies for restoring soil health, maintaining productivity, and bolstering orchard resilience against environmental change.

Chapter 2: Rice Husk Biochar Suppresses White Root Rot Disease Caused by *Rosellinia necatrix* in Japanese Apricot Trees Independent of Arbuscular Mycorrhizal Fungi and Bahiagrass
（イネ籾殻バイオ炭は、アーバスキュラー菌根菌やバヒアグラスに依存せず、*Rosellinia necatrix* によって引き起こされるウメ白紋羽病を抑制する）

White root rot caused by *Rosellinia necatrix* severely affects Japanese apricot productivity. In this study, a commercial rice husk biochar (Brh) and a bamboo biochar (Bb) were evaluated for its disease-suppressive effects, alone and in combination with arbuscular mycorrhizal fungi (AMF) and bahiagrass (Bg), in sterile conditions. *In vitro* assays revealed that neither Brh nor Bb inhibited pathogen growth, with hyphal expansion reaching 22 % higher than control at maximum Brh concentration. However, *in vivo*, biochar treatments significantly reduced disease severity: Brh decreased white root rot severity by 25 % at 26 days; BrhAMF by 20 %. Disease scores at 12 days post-inoculation were 2 ± 0.7 (Brh), 1.5 ± 0.3 (BrhAMF), compared to 4.2 ± 0.25 in controls. Plant growth was positively affected: fresh biomass increased by 79.4 % (AMF), 125.4 % (BrhAMF), and 62.2 % (BbAMF) vs. control. Shoot weights in the BrhAMF group reached 26.6 g versus 19.15 g for AMF alone, indicating enhanced nutrient availability. Leaf nitrogen content was 0.35 g in BrhAMF and 0.34 g in AMF-only plants, while leaf phosphorus rose to 0.027 g in BrhAMF, compared to 0.01 g in controls. Mycorrhizal colonization dropped from 50.4 % in AMF to 27 % with combined BrhAMF, likely due to increased leaf P. Overall, Brh efficiently suppressed white root rot independently of AMF and Bg.

Chapter 3: Interactive Effects of Biochar and Cover Crops on Soil Bacterial Community and Enzyme Activities.
（土壌細菌群集と酵素活性に対するバイオ炭と草生栽培の相互作用効果）

Investigation into Japanese apricot orchards revealed that co-application of biochar and cover crops change the soil bacterial community and enzyme activities. Brh substantially augmented humus content. Cover crops here represented by the Bg and white clover (Wc) enriched microbial diversity. Brh amendment led to significant increases in beneficial bacterial families responsible for nutrient cycling and organic matter decomposition, such as *Bradyrhizobiaceae,* did not increase enzyme activity, which was notably enhanced by cover crops or Bb. Findings indicate that the benefits from cover crops or biochar are varied, and co-application does not holistically enhance soil bacterial community or enzyme activities.

Chapter 4: Biochar and Cover Crops Induce Soil Fungal and Mycorrhizal Community Structure Shifts in a Perennial Orchard System.
（多年生果樹園システムにおけるバイオ炭および草生栽培による土壌糸状菌および菌根菌群集の変動）

This chapter explores the impact of biochar and cover crop co-application on the structure and function of soil fungal and AMF communities in perennial Japanese apricot orchards. Over a eighteen months period, some integrated and single cover crop amendments generated pronounced increases in the diversity and abundance of beneficial fungal and AMF taxa. BrhWc and BrhBgWc showed an increase in abundance of *Mortierellaceae* (AMF) and *Acaulosporaceae* (AMF). Correlation analyses revealed links between AMF family abundance and some soil enzyme activities, and high correlations between *Mortierellaceae* and soil enzyme activities, as well as predicted soil metabolic functions.

Chapter 5:　General discussion and Conclusion.　（総括と結論）
This thesis demonstrated that biochar could mitigate white root rot symptoms in Japanese apricot seedlings *in vivo*. In field trials, the combination of cover crops and biochar modified soil microbial communities and enzyme activities. These shifts were not uniform, but instead occurred in specific bacterial, fungal and AMF groups. In particular, some cover crops and their combinations with biochar enhanced the abundance of *Mortierellomycota* and *Acaulosporaceae.* In addition, AMF community composition correlated with changes in protease, invertase and arylsulfatase activities under Brh or Bb application. Collectively, these results offer system-specific evidence that strategic application of biochar and cover crops can influence soil microbial communities and their linkage with enzyme activities.